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SPECIFIC ACUTE LOSSES OF VESTIBULAR FUNCTION IN MAN FOLLOWING UNILATERAL SECTION OF ONE OR ALL COMPONENTS OF THE EIGHTH CRANIAL NERVE

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13. ABSTRACT

Functional tests of the specific auricular organs were administered to four patients who had the common complaint of disabling vertigo and tinnitus. Diagnosis of unilateral inner ear disease or disorder was aided by a relative decrease in right- or left-ear response as recorded by certain techniques, while other methods demonstrated undisturbed function. Partial and complete VIIIth nerve sections completely eliminated the tinnitus and severe symptoms of vertigo in each patient, as well as greatly reduced his extremely high susceptibility to motion sickness, although it caused a short-term increase in instability in walking and standing. Specific auricular organ loss of function was related to the side and extent of the surgical interference. Possible clinical implications are discussed.

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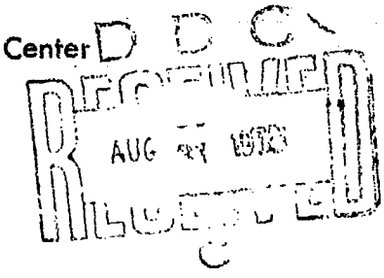

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SUMMARY PAGE

THE PROBLEM

1) To determine the effects of partial and of complete unilateral nerve sections in terms of specific labyrinthine and related functions in four patients.

2) To point up the value of selective specific tests of labyrinthine function.

FINDINGS

Functional and provocative tests involving the sensory organs of the inner ear were administered to four patients, and the findings, including unequal right-left ear responses, were used in differential diagnosis. Partial and complete unilateral VIIIth nerve sections completely eliminated the tinnitus and severe vertigo symptoms in each patient, and also selectively and differentially altered labyrinthine and related behavioral responses. Possible clinical implications of the findings are discussed.

ACKNOWLEDGMENTS

Our great appreciation is expressed to the four patients of this study who co-operated so well and willingly traveled great distances to serve as our subjects in spite of their physical conditions.

The important task of evaluating these patients pre- and postoperatively in terms of their ataxia and postural equilibrium was performed by A. R. Fregly, Ph. D., and Mr. T. L. Trimble, and of hearing by Mr. J. W. Green and Mr. J. M. English and is gratefully acknowledged by the authors.

INTRODUCTION

A classical approach to the study of the role of the vestibular systems in animal subjects involves either selective ablation of structural elements in the end organs or section of their nerve supply. Valuable as these studies may be, they have limited application to man because the roles played by the vestibular systems may differ greatly in man and animal. For this reason it is highly important to exploit as fully as possible any human-subject material which fortuitously may become available. One object of the present study was to compare the vestibular and related responses of four patients before and after partial or complete unilateral sectioning of the VIIIth nerve in the treatment of severe vertigo; a second was to evaluate the measured responses with regard to diagnosing a unilateral disorder.

PROCEDURE

Table I includes a résumé of the experimental design that briefly describes the four patients, their history of vertigo, the pre- and postoperative diagnosis, the time-interval preceding and following surgery when special tests were applied, and the various tests administered. The entire test battery was completed within approximately 2 ½ days. A more complete description of the surgical techniques, individual case histories, and the labyrinthine-type tests is presented in the sections to follow.

SURGICAL TECHNIQUES

Translabyrinthine Approach (1)

The patient was placed supine on the operating table with his head turned so that the involved side was up. Under general anesthesia and sterile technique the post-auricular skin and subcutaneous tissues were infiltrated with a local anesthetic agent, and an incision was made with cutting current 1 cm behind the postauricular fold. The temporalis muscle was reflected and self-retaining retractors were used.

The posterior bony external auditory canal was thinned but preserved. The incus and the lateral semicircular canal with the facial nerve immediately inferior to it were identified. The semicircular canals were next removed, exposing the vestibule. The facial nerve was skeletonized at the external genu. The membranous labyrinth including the utricle, saccule, and ampullae of the semicircular canals was removed. The hard bone of the petrous apex was removed medially with a diamond drill to expose the superior and inferior vestibular nerves and the dura of the posterior part of the internal auditory canal. Bone was carefully removed from the superior vestibular nerve to its lateral end near the ampulla of the vertical canal and from the internal auditory canal until the transverse crest was clearly seen. Finally, just enough bone was removed from the superior part of the internal auditory canal to identify the canal of the facial nerve.

The superior vestibular nerve was removed from its lateral attachment and reflected posteriorly away from the unharmed facial nerve. The dura of the internal

auditory canal was minimally opened, and a 3-mm hook was passed forward around the cochlear and inferior vestibular nerves. It was rotated inferiorly along the anterior wall and withdrawn with the point against the inferior wall of the canal, thus encircling the nerves of the inferior chamber and sectioning them. The incus was removed, and a free graft of temporalis muscle was packed into the attic to prevent a possible leak of cerebrospinal fluid through the auditory tube. This was done carefully to avoid injury to the tympanic part of the facial nerve.

Another free-muscle graft was placed over the defect in the dura and was held in place by a single 5-0 silk suture anchored to the dura. The wound was closed tightly with interrupted subcutaneous 2-0 chromic catgut sutures and a mastoid dressing was applied.

Middle Cranial Fossa Approach (2,3)

Under general anesthesia supplemented by local infiltration, an incision similar to that for treatment of tic douloureaux was made above the ear. A 1 $\frac{1}{2}$-inch square of bone was removed from the squamous portion of the temporal bone, and dura of the temporal lobe was elevated with the self-retaining retractor. The middle meningeal artery was traced to the foramen spinosum. The great petrosal nerve was identified just posterior to the foramen. Bone was removed from this nerve until the geniculate ganglion was exposed, and the facial nerve was followed to the internal auditory canal. A small portion of bone was removed from the superior part of the internal auditory canal so that both the facial nerve and the superior vestibular nerve were clearly identified. When this had been done, a hook was placed around the superior vestibular nerve and also the inferior vestibular nerve and they were sectioned.

LABYRINTHINE AND RELATED TESTS

Functional Tests

Ocular counterrolling as measured by the photographic method (4,5) was used to calibrate otolith function. Several photographic recordings of natural iris landmarks were made in the upright and in the following tilt positions: ± 17.5, ± 25.0, ± 37.0, ± 50.0, ± 64.0 degrees. This procedure was repeated several times over a 3-day period both pre- and postsurgery. Rightward-leftward sequence of tilt was randomized. Patient NU was also tested pre- and postoperatively after being tilted to 75 degrees, at approximately 25°/sec, in the rightward and leftward directions according to the following sequence: right, left; left, right. Several minutes' duration separated each tilt test. Photographs were made upon reaching the tilt position and at every second up to 25 seconds while he was held in this position.

The threshold of response of the lateral semicircular canals was determined by the method described by McLeod and Meek (6).

Following the threshold caloric test, caloric irrigations were continued according to the Fitzgerald-Hallpike technique (7), but modified to the extent that electronystagmographic (ENG) recordings were made. Subjects were tested with eyes open in darkness and without a visual fixation target, except as noted in Table I. Excitability and directional preponderance of nystagmus were calculated by the method of Jongkees and Philipszoon (8), using the maximum velocity of the slow phase nystagmus as the principal response parameter.

Details of the oculogyral illusion threshold method are to be published elsewhere (9). The subject was secured in an accurately servo-controlled rotating chair and fitted with a goggle device (10) that was supported by a custom-fitted biteboard assembly and contained a luminous-line target. The chair was rotated according to any one of several 24 double (up/down) ramp velocity profiles, ranging in log steps from 0.096 to 6.000°/sec^2, which were separated by a period of constant rotation at the terminal peak velocity of each profile; i.e., constant acceleration for 25 seconds, constant velocity for 20 seconds, and constant deceleration for 25 seconds to a stop. The subject's task was to identify, when signalled at specific elapsed times during the profile, the apparent lateral movement, if any, of the target. A threshold for clockwise (acceleration) and counterclockwise (deceleration) as well as acceleration in the reverse sense was determined by a double-staircase method of introducing acceleration step levels.

A standardized audiometric test (Rudmose APJ-4A, or Békésy, MAICO M-10 audiometer) of pure tones was performed pre- and postoperatively.

A quantitative battery of tests was administered to determine, pre- and postoperatively, ataxia and postural equilibrium by the Graybiel-Fregly short-version method (11).

Provocative Tests

Motion sickness susceptibility was determined by exposing the patients to Coriolis or cross-coupled angular accelerations that stimulate the canals (12-14) and to rotating linear vectors (15, 16) that stimulate the otolithic receptors. Susceptibility in each of these two modes of stressor stimulations is quantitatively expressed on a scale of 0 to 100, with 100 representing essential immunity to motion sickness. The Coriolis Sickness Susceptibility Index (CSSI) is calculated simply by multiplying the appropriate E factor for the rpm used in the test by the number of head movements (N) required to elicit M IIA (17), and Otolithic Sickness Susceptibility Index (OSSI) is calculated by multiplying the amount of time in minutes it takes an individual to reach the endpoint of M IIA by 2.5.

RESULTS

The pre- and postoperative findings expressed in both qualitative and quantitative terms with respect to the diseased and normal ear of each patient are summarized in Table I and explained on individual bases in the following sections.

PATIENT JU

Case History

JU, a 37-year-old woman, had a lumbar laminectomy, which was followed 30 hours later by rotary vertigo and an uncomfortable feeling in the right ear. The laminectomy was complicated by more than usual loss of blood, hypotension, and anemia. A mild right-sided tinnitus and a feeling of fullness developed in her right ear which persisted, but without a hearing loss. Up to the time of inner ear surgery, 16 months later, she continued to experience unsteadiness and episodes of vertigo primarily when her head was back and to the right. Patient noted that if she inadvertently assumed this position in sleep, it could cause her to awaken with nausea and vomiting. The provisional diagnosis was right labyrinthine lesion (utricular), and treatment was right superior vestibular nerve section via the middle fossa. After surgery no tinnitus was noticed by the patient, but she initially reported a "pulsation" in her right ear, which subsequently disappeared. The surgery caused unsteadiness in walking, with a tendency to fall to the right, which later improved. She has continued treatment for low blood pressure (Indural and Neosynephrine Hydrochloride).

Labyrinthine and Related Tests

Presurgery - JU manifested normal ocular counterrolling with respect to average magnitude and variability, but the symmetry of this response was abnormal in that there was much greater eye roll when tilted toward the normal ear than toward the diseased ear (Figure 1). Thresholds of response to caloric irrigation were normal, but the modified Fitzgerald-Hallpike test revealed 29.2 per cent less excitability of the right than the left lateral canal and 23.0 per cent directional preponderance to the left. The oculogyral illusion threshold response was slightly higher for the left than the right ear ampullofugal direction. High-frequency hearing loss, but within normal limits, was recorded (Figure 2). Moderate postural disequilibrium, but no ataxia, was measured (Table II). JU proved to be the most susceptible to motion sickness of the four patients; she executed only 15 head movements while rotating at 2.5 rpm and sustained just 1.4 minutes of passive off-vertical rotation before exhibiting the test endpoint of Malaise IIA.

Postsurgery - JU's ocular counterrolling response following surgical sectioning of her right superior vestibular nerve was found to be reduced, primarily when she was tilted leftward (left ear inferior), but there was no change in eye roll stability. Cupular threshold response to cold-water irrigation increased in the operated ear. Essentially, relative canal excitability was lost on the operated side, and directional preponderance was toward the unoperated ear. For technical reasons, the laboratory

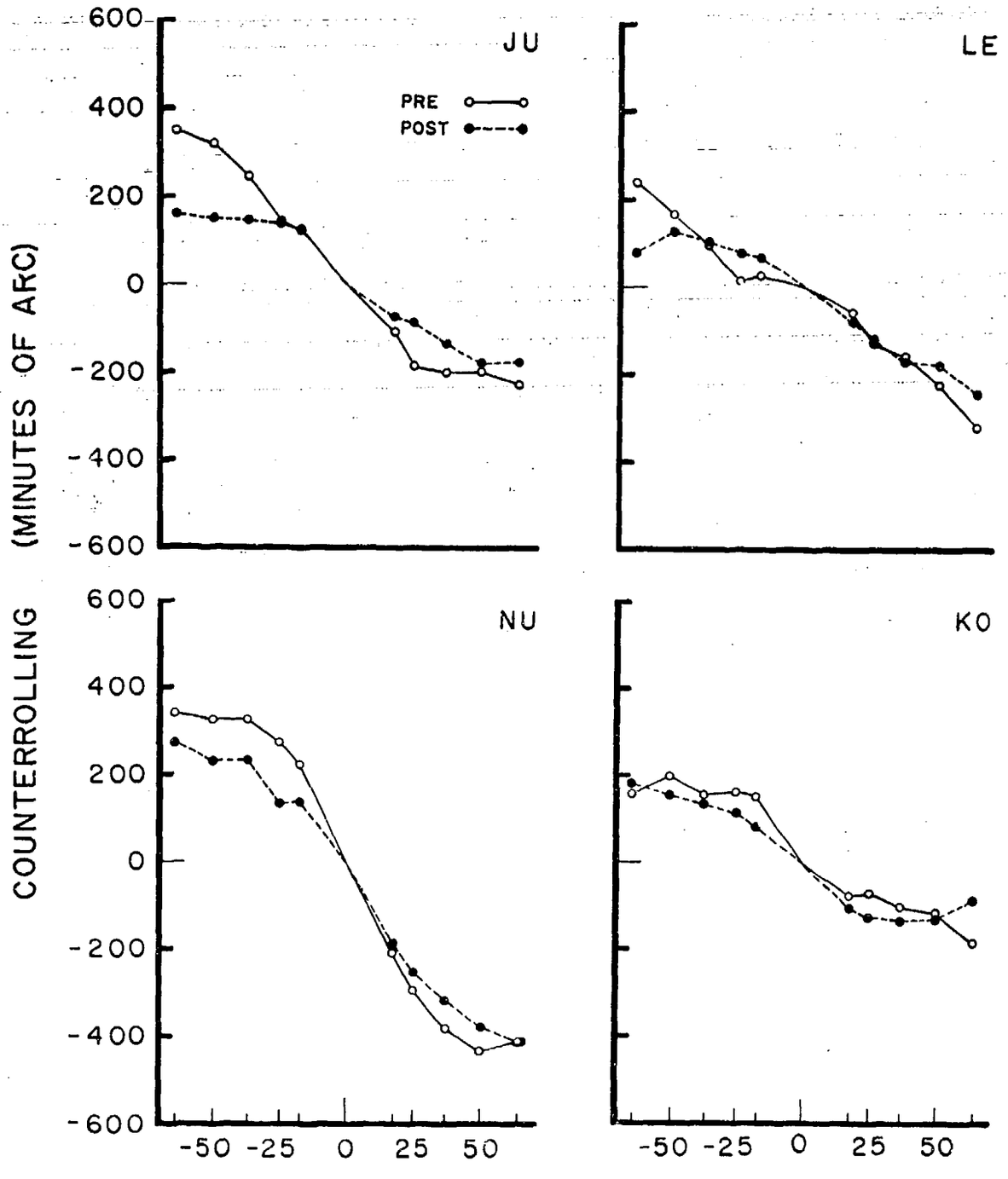

Figure 1

Average Pre- and Postoperative Counterrolling Response for the Four Patients

Table I

PATIENT	VERTIGO DURATION (MONTHS)	DIAGNOSIS SIDE OF LABYRINTHINE DISORDER	TIME OF TEST*	OCULAR COUNTERROLLING (MINUTES OF ARC) TILT TOWARD DISEASED EAR	TILT TOWARD NORMAL EAR	CI†	CALORIC RESPONSE THRESHOLD (°C) DISEASED EAR	NORMAL EAR
JU, AGE 37 ♀	16	RIGHT	-17	SLIGHTLY BELOW NORMAL	NORMAL		NORMAL	NORMAL
SURGICAL SECTION RIGHT SUPERIOR VESTIBULAR NERVE ▶				194	320	257		
	NONE	CONFIRMED	104	UNCHANGED	GREATLY DECREASED		INCREASED	UNCHANGED
				179	155	167	30.0	
LE, AGE 57 ♂	166	LEFT	-5	BELOW NORMAL	LOW NORMAL		NORMAL	NORMAL
SURGICAL SECTION LEFT SUPERIOR VESTIBULAR NERVE ▶				161	244	202		
	NONE	CONFIRMED	70	SLIGHTLY DECREASED	SLIGHTLY DECREASED		INCREASED	UNCHANGED
				130	178	154	30.5	
NU, AGE 40 ♂	14	RIGHT	-9	HIGH NORMAL	NORMAL		NORMAL	NORMAL
SURGICAL SECTION RIGHT SUPERIOR AND INFERIOR VESTIBULAR NERVES ▶				434	327	380		
	NONE	CONFIRMED	83	SLIGHTLY DECREASED	GREATLY DECREASED		GREATLY INCREASED	UNCHANGED
				376	231	304	19.6	
KO, AGE 51 ♂	13	LEFT	-31	SLIGHTLY BELOW NORMAL	BELOW NORMAL		NORMAL	NORMAL
SURGICAL SECTION LEFT VIIIth NERVE ▶				183	139	161		
	NONE	CONFIRMED	102	UNCHANGED	UNCHANGED		LOST (NO RESPONSE AT 6.0)	UNCHANGED
				164	127	146		

*Initial day of labyrinthine testing in relation to surgery

†Calculated as one-half the sum of eye roll measured in minutes of arc at the 50° rightward and leftward tilt positions

**Based upon threshold caloric response

‡Subject's eyes open; laboratory illuminated

Résume of Labyrinthine and Related Test Results of Four Patients Before and After Partial and Complete Unilateral VIIIth Nerve Sections

FITZGERALD-HALLPIKE (MODIFIED) CALORIC TEST		OCULOGYRAL ILLUSION THRESHOLD (°/SEC²)		HEARING		POSTURAL EQUILIBRIUM	ATAXIA	MOTION SICKNESS SUSCEPTIBILITY	
RELATIVE LOSS OF EXCITABILITY (%)	DIRECTIONAL PREPONDERANCE (%)	AMPULLOFUGAL ACCELERATION							
DISEASED EAR	TOWARD NORMAL EAR	TOWARD DISEASED EAR	TOWARD NORMAL EAR	DISEASED EAR	NORMAL EAR			CSSI	OSSI
MODERATE	SIGNIFICANT	NORMAL	ELEVATED	NORMAL	NORMAL	FAIR	NONE	EXTREMELY HIGH	EXTREMELY HIGH
29.2	23.0	0.150	0.600					0.2	1.4
COMPLETE	INCREASED	UNCHANGED	DECREASED	IMPROVED	UNCHANGED	DECREASED	SEVERE	LOW	ENDPOINT NOT REACHED
100.0	33.8	0.150	0.150					28.1	
INSIGNIFICANT	INSIGNIFICANT	NORMAL	NORMAL	MODERATELY DECREASED	SLIGHTLY DECREASED	GOOD	NONE	EXTREMELY HIGH	AVERAGE
		0.096	0.060					0.1	19.3
ESSENTIALLY COMPLETE	INCREASED	GREATLY INCREASED	SLIGHTLY INCREASED	UNCHANGED	UNCHANGED	POOR	SEVERE	ENDPOINT NOT REACHED	ENDPOINT NOT REACHED
97.3	30.4	0.950	0.120						
INSIGNIFICANT	INSIGNIFICANT	NORMAL	NORMAL	SLIGHTLY DECREASED	SLIGHTLY DECREASED	POOR	SEVERE	EXTREMELY HIGH	EXTREMELY HIGH
		0.096	0.350					0.3	3.6
COMPLETE**	NOT MEASURED	GREATLY INCREASED	GREATLY INCREASED	GREATLY DECREASED	UNCHANGED	DECREASED	INCREASED	HIGH	AVERAGE
100.0		0.475	1.200					1.4	16.8
SEVERE	SIGNIFICANT	NORMAL	NORMAL	ALMOST COMPLETE LOSS	SLIGHTLY DECREASED	GOOD	NONE	HIGH	AVERAGE
57.0	21.2	0.150	0.380					2.1	22.0
COMPLETE‡	GREATLY INCREASED	INCREASED	INCREASED	COMPLETE LOSS	UNCHANGED	POOR	SEVERE	AVERAGE	ENDPOINT NOT REACHED
100.0	73.8	0.380	0.600					13.3	

Table II

Postural Equilibrium and Ataxia Percentile Scores of the Four Patients
Obtained Pre- and Postoperatively by the Graybiel-Fregly Short Version Test Method

		JU		LE		NU		KO	
		Pre	Post	Pre	Post	Pre	Post	Pre	Post
Rail Tests	3/4" Walk, Eyes open	25*	65	55	15	15	6	42	42
	3/4" Stand, Eyes open	37	25	87	44	40	9	83	13
	2-1/4" Stand, Eyes closed	15	15	76	1	1	3	50	1
Floor Tests	Walk, Eyes closed	99	1	99	1	99	99	99	2
	Sharpened Romberg, Eyes closed	24	6	3	19	1	5	36	1
	Stand Right Leg, Eyes closed	45	18	21	12	1	1	14	1
	Stand Left Leg, Eyes closed	28	15	33	7	4	1	51	1

*Percentile scores

chair used to measure the oculogyral illusion threshold was inoperable on JU's first revisit following surgery, and this test only was conducted on a second revisit (197 days postsurgery). It was found that JU's thresholds for both directions of acceleration approached or reached the lower limit of the test device. A slight improvement in hearing was measured (Figure 2). JU revealed frank ataxia and increased postural disequilibrium with eyes closed; aided by vision, however, she performed well (65 percentile score) in walking a 3/4-inch-wide rail. In marked contrast to her baseline measurements JU was symptomless in the off-vertical rotation test and showed a dramatic decrease in the susceptibility to cross-coupled angular accelerations.

PATIENT LE

Case History

LE, a 57-year-old man, had a history of vertigo of 14 years' duration prior to the first examination. He reported that 1 year before his initial episode, he fell from a truck. His major symptoms were a tendency to fall and to revolve to the left, which disabled him for periods of ½ to 6 hours; relief was achieved by lying on his right ear. He described each attack "as if someone hit me with a board"; he would sweat excessively, and feel flushed, but his wife observed that he looked as "white as a sheet." He complained of some numbness and a "needle" sensation that spread from the left ear to the temporal region, and he occasionally experienced tinnitus on the left side. His heart would pound rapidly after the attack started. He urinated excessively (over 1 quart) following an attack. Tomograms of the temporal bone and neurological examination were completely negative. Drug (Marezine) therapy was less than successful. The provisional diagnosis was left labyrinthine vertigo, possibly caused by vestibular neuronitis, and the treatment was left superior vestibular nerve section via the middle fossa. After surgery the patient reported that the tinnitus as well as the spells of vertigo previously evoked when lying on his left ear had disappeared, and his intermittent instability noted in walking seemed to be improving rapidly.

Labyrinthine and Related Tests

Presurgery - The average counterrolling response was found to fall within the range found in subjects with severe bilateral labyrinthine defects (5), and its intertest variability was unusually great (Figure 3). The thresholds of response of the lateral canals were normal bilaterally, and the modified Fitzgerald-Hallpike test revealed neither right-left labyrinthine nor directional imbalance. The oculogyral illusion threshold in each direction of acceleration was equivalent and well within normal limits. Slight hearing losses (left greater than right) were recorded throughout the frequency test range (Figure 2). The sharpened Romberg test indicated marked postural disequilibrium (3rd percentile), but in the other equilibrium tests (Table II) he revealed no ataxia and only slight imbalance while standing. LE displayed severe susceptibility to the Coriolis type of motion sickness (CSSI = 0.1) and average susceptibility to off-vertical rotation. During the former test, LE spontaneously reported that he experienced sensations that were "identical to his attacks" of vertigo, which occurred typically when walking or sitting.

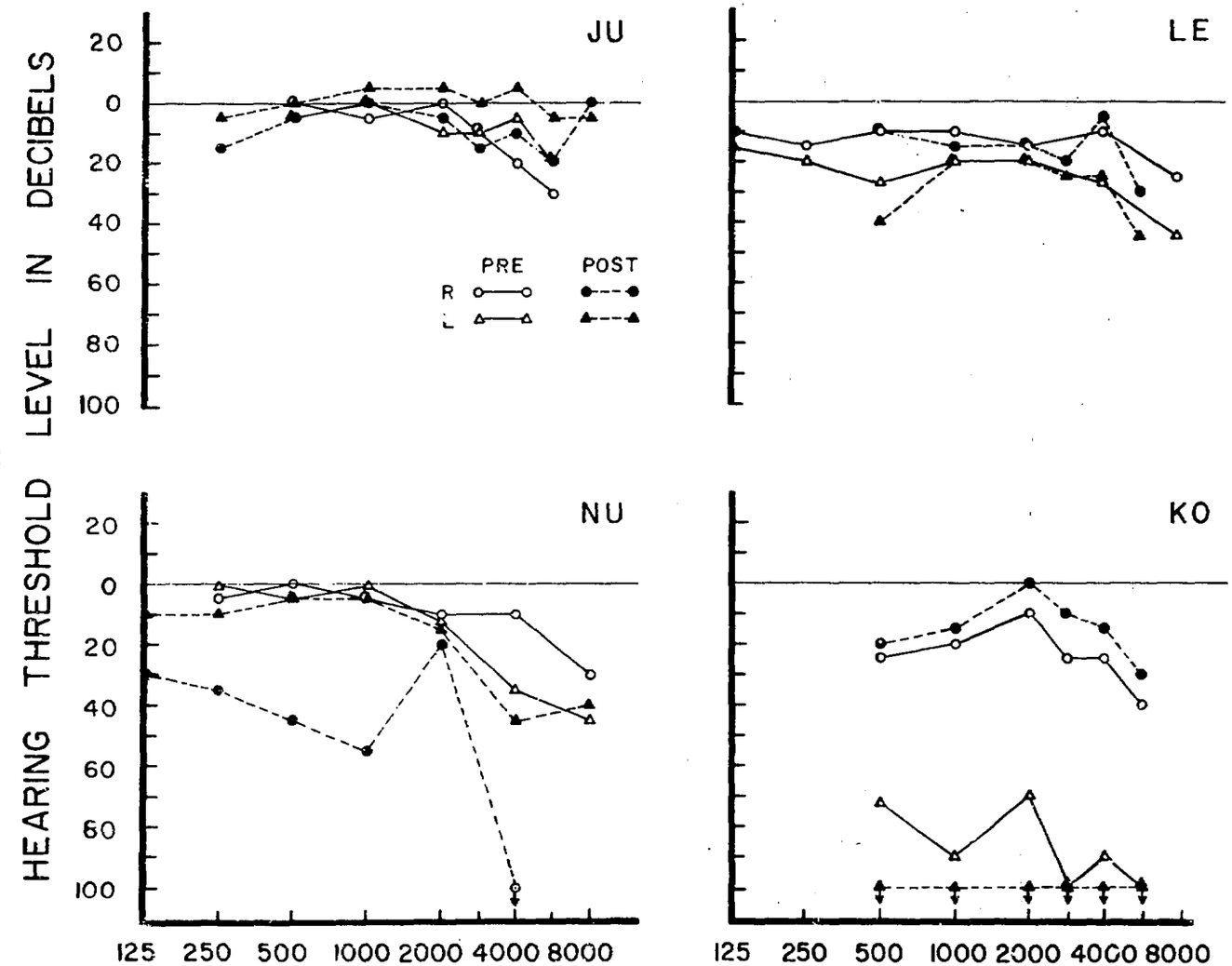

Figure 2

Pre- and Postoperative Results of Audiometric Tests

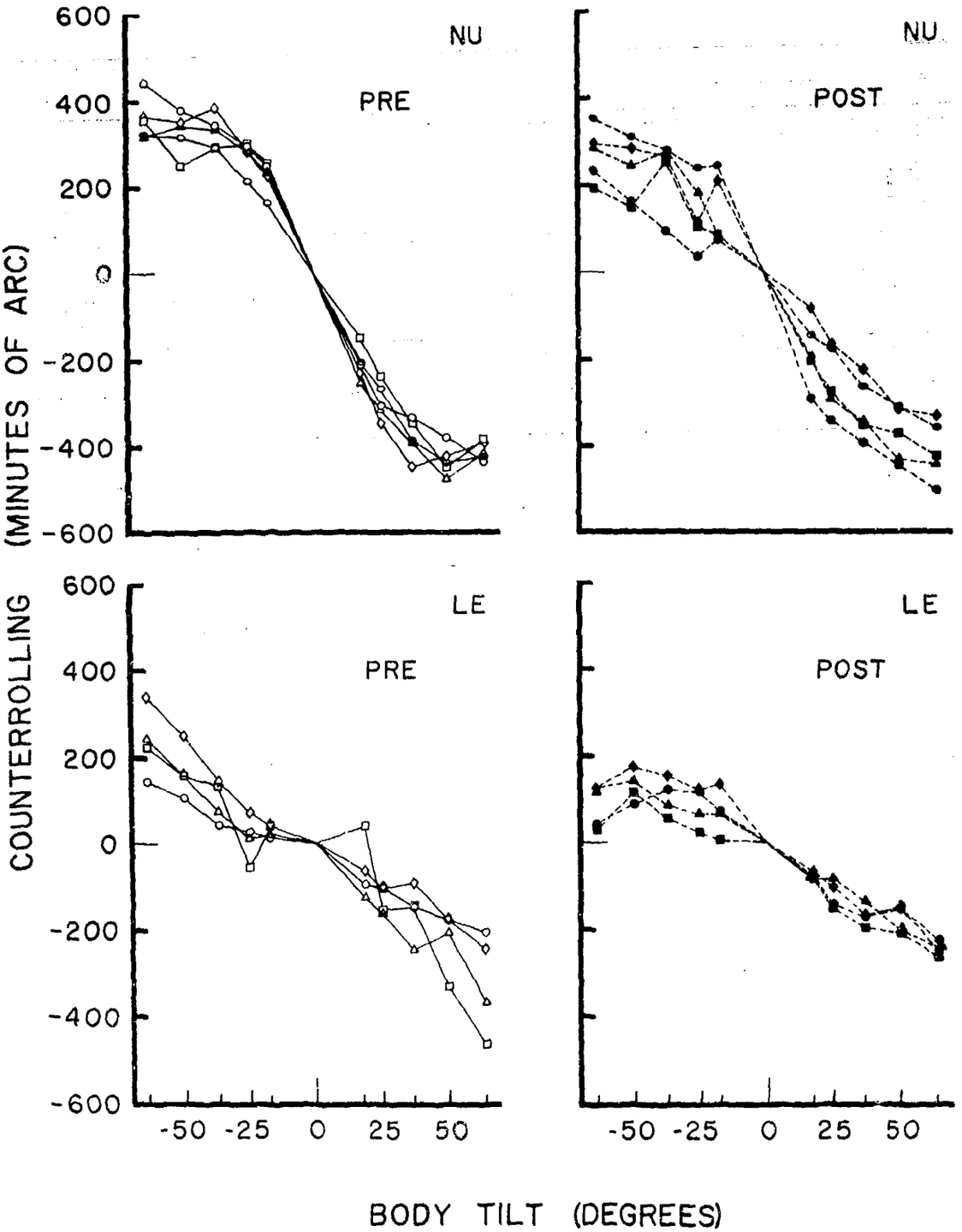

Figure 3

Test-to-Test Variability of Counterrolling of Patients NU and LE Measured Pre- and Postoperatively

Postsurgery - After surgical sectioning of the left superior vestibular nerve, slight reduction from the below-normal presurgery level of the average counterrolling was recorded (Figure 1), but the surgery had an apparent quieting effect upon the intersessional variability of the counterrolling, particularly when the operated ear was uppermost. Cold-water-irrigation threshold of response was increased in the operated ear. Essentially complete loss of left-ear suprathreshold excitability (modified Fitzgerald-Hallpike test) was found; directional preponderance as expected was toward the normal ear. There was a marked increase in the oculogyral illusion threshold for left and slight increase for right ampullofugal acceleration. Hearing was not significantly changed. Although there was some improvement in the sharpened Romberg score (Table II), severe ataxia and greatly decreased postural equilibrium were measured. Tolerance to motion increased dramatically; only mild symptoms far short of the test endpoint (Malaise IIA) were evoked in each of the provocative tests.

PATIENT NU

Case History

NU, a 40-year-old man, sustained a skull fracture in an automobile accident. When ambulatory 2 weeks later, he complained of dizziness and postural vertigo, which persisted and rendered him unable to work. He also sustained a right hearing loss and tinnitus temporarily for a few weeks following the accident. Vertigo was often triggered by movement while recumbent, and violent rotary nystagmus could be evoked for a period of about 10 seconds by placing his right ear down. Roentgenograms revealed a linear fracture involving the right frontal bone, beginning at the superior orbital ridge and extending back toward the temporal region. Roentgenographic and neurological examinations of the cervical spine were negative. An electroencephalogram (EEG) showed only minor disrhythmic changes over both Sylvian regions, which were considered to have no localizing or differentiating diagnostic significance. The provisional diagnosis was right labyrinthine lesion, and the treatment was right superior and inferior vestibular nerve section via the middle fossa. After surgery the patient felt more secure and stable in walking and his positional vertigo disappeared. His headaches were not so severe nor so frequent as before surgery. Although his wife became airsick in a very turbulent flight to Pensacola for his postsurgical tests, he reported no symptoms from this experience.

Labyrinthine and Related Tests

Presurgery - Counterrolling was normal with respect to its magnitude, symmetry, and intertest variability of average recordings (Figures 1 and 3). However, when tilted laterally toward his diseased (right) ear, in contrast to tilting in the opposite direction, the torsional (negative counterrolling) position of NU's eye as measured over a span of several seconds was highly unstable (Figure 4). The occasional breaks in the curves indicate when the patient's eye deviated from its proper fixation position and eye roll was unmeasurable. Irrigation thresholds of response were well within normal limits bilaterally, and no significant labyrinthine or directional preponderance was registered

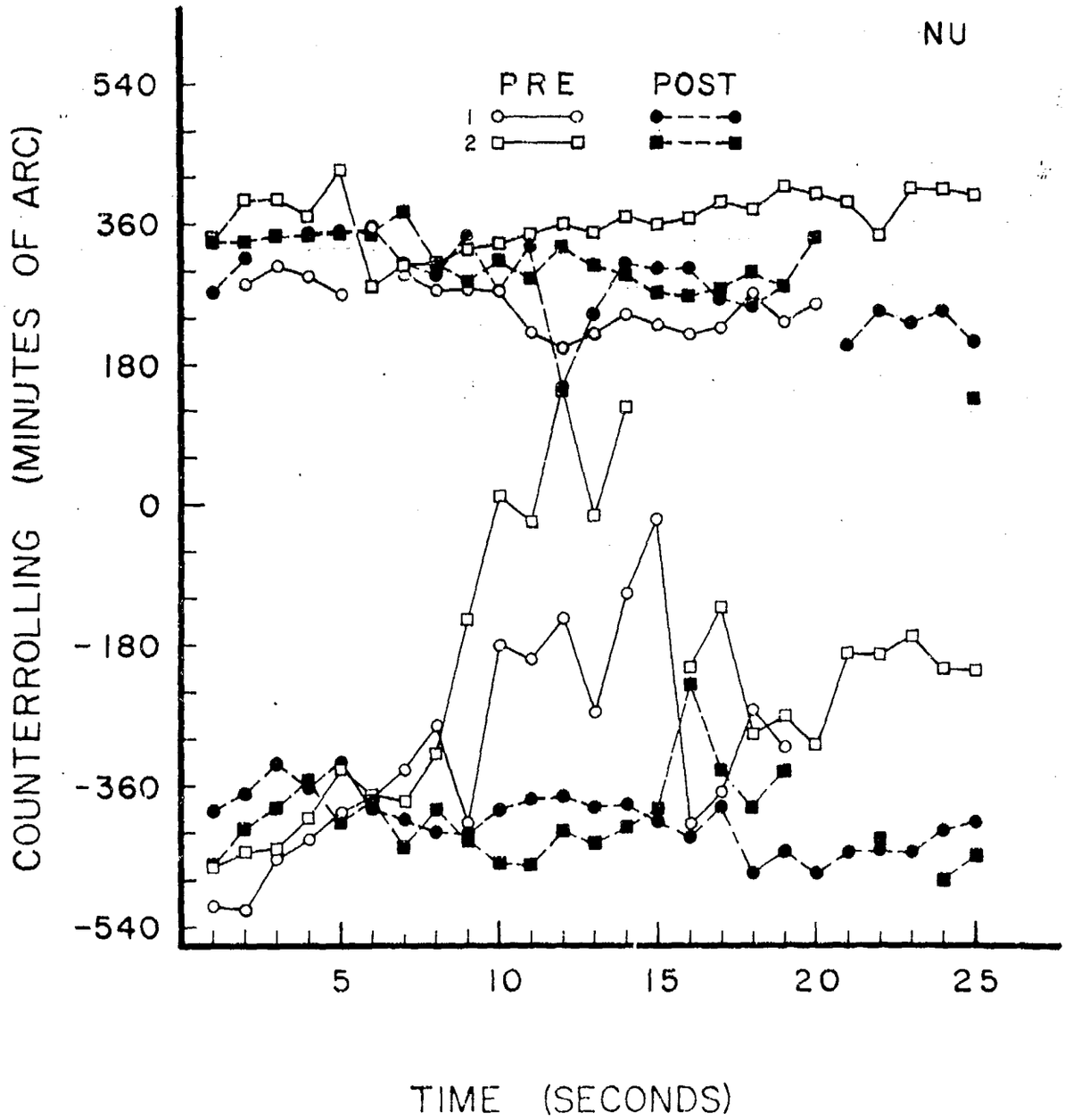

Figure 4

Counterrolling (CR) Response of Patient NU Tilted 75° Laterally Toward His Normal Ear (+ CR Values) and Toward His Diseased Ear (-CR Values) As Recorded in Two Test Sequences Both Pre- and Postoperatively

by the modified Fitzgerald-Hallpike technique. The oculogyral illusion threshold for right ampullofugal acceleration was below the testing limit ($0.096^{\circ}/sec^2$) of the existing hardware; for the reverse direction it was substantially higher, but still within normal range. A slight high-frequency loss of hearing was measured (Figure 2). With the exception of his excellent ability to walk on the floor with eyes closed, NU performed other walking and balance tests extremely poorly (Table II). His susceptibility as measured in both the Coriolis and off-vertical tests of motion sickness was extremely high.

Postsurgery - Several weeks after sectioning the right superior and inferior vestibular nerves, the unstable ocular and presumably otolithic activity that had been specific for the rightward-tilt direction could not be elicited on two separate occasions and, moreover, was similar to the leftward response that remained unchanged by the surgery (Figure 4). The intersessional variability of the average counterrolling values, however, was greater than during presurgery (Figure 3). The irrigating temperature had to be reduced to 19.6° C to elicit a threshold response, considerably below the standard cold temperature of the Fitzgerald-Hallpike test, which, as a result, registered no excitability of the operated ear. Clearcut increases in the oculogyral illusion thresholds for both directions of acceleration were recorded. Except at 2000 Hz, substantial loss of hearing of the right ear was sustained. NU was still able to walk well on a flat surface with his eyes closed, but his poor presurgery balance and other ataxia scores in most cases dropped even lower. Although he remained very susceptible to motion sickness, he could tolerate much more vestibular stressor stimulation following surgery. Furthermore, the "mock vertigo attack" evoked in the presurgery period by the Coriolis sickness susceptibility test could not be elicited.

PATIENT KO

Case History

KO, a 51-year-old man, in November 1968 turned his head while operating a motor vehicle. This evoked an initial episode of vertigo that persisted for 3 to 4 hours and was accompanied by vomiting. One month later a series of attacks began which led to hospitalization. The vertigo was most intense when his eyes were open and severe enough to require him to lie down to prevent falling and developing severe symptoms with the world "spinning around me." The physical examination was within normal limits, except for diabetes, which was controlled by Diabinese, and a hearing loss; an audiogram showed hearing for the right ear at the 12-dB level with 100 per cent speech discrimination. Electronystagmography revealed a 4°/sec right beating spontaneous nystagmus and 46 per cent reduced vestibular response to bithermal caloric stimulation (18). The provisional diagnosis was left labyrinthine vertigo (vascular occlusion), and the treatment was a translabyrinthine complete left VIIIth nerve section. After surgery the patient stated that about half the day he felt as if he would fall to the left and sitting for any length of time caused unsteadiness upon standing. He reported an occasional headache, usually frontal or occipital. No medication has been required, except for his diabetes, and he has fully resumed his usual activities.

Labyrinthine and Related Tests

Presurgery - KO manifested stable but below-normal otolith function bilaterally; his ocular counterrolling approached the limit of the range of response of individuals with severe labyrinthine defects (5). Threshold response to thermal irrigation was normal bilaterally, but suprathreshold stimulation (modified Fitzgerald-Hallpike technique) revealed substantially less excitability in the diseased left ear and right directional preponderance. Ampullofugal acceleration threshold toward the right ear was found to be relatively higher than toward the left, but well within the normal range. Decreased hearing of his right ear and almost complete loss of hearing of his left ear were found (Figure 2). No ataxia and slight postural disequilibrium were recorded (Table II). Tests of Coriolis and off-vertical rotation types of motion sickness revealed extremely high and moderate levels of susceptibility, respectively.

Postsurgery - Complete sectioning of the left VIIIth nerve resulted in no essential change in stability and in the already reduced otolithic (counterrolling) response. Complete loss of left-ear cupular function was demonstrated by the lack of response to irrigation with 6.0° C water. Marked preponderance was directed toward his normal right ear. The oculogyral illusion threshold of response to both right and left ampullofugal accelerations increased. Loss of hearing of his left ear became complete. There was a marked increase in postural disequilibrium (Table II), with severe ataxia with eyes closed but no change in walking ability with vision. Susceptibility to motion sickness was found to be greatly lessened; with the Coriolis provocative test mode a sixfold decrease was measured and no symptoms were provoked with off-vertical rotation.

DISCUSSION AND SUMMARY

Failure to demonstrate preoperatively a unilateral canalicular loss of function in these patients by a caloric threshold technique would seem to indicate that the threshold of response was more resistant to alteration by the disorder and consequently was without diagnostic value. In contrast, the caloric threshold test after surgery demonstrated in quantitative terms substantial reductions in the response of the operated ear to cold-water irrigation. The oculogyral illusion threshold in three patients in the preoperative period was higher when ampullofugal acceleration was directed toward the normal ear; in the fourth patient (LE) the threshold was extremely low and essentially equal in both directions. Postsurgery, this response threshold increased in both directions of acceleration and without any consistent pattern among three patients. Patient JU, who had more recovery time than the other patients prior to the administration of this particular test, revealed a decrease in threshold of response, with ampullofugal acceleration toward the normal ear.

The audiometric test and certain of the vestibular function measurements, in some cases, clearly indicated right/left differences that proved to be diagnostically valid. Pure tone discrimination measurements identified the affected side in two of the patients (LE, KO) who suffered unilateral suppression of auricular function, but not in the other two (JU, NU).

The modified Fitzgerald-Hallpike test that relies upon suprathreshold stimulation of the lateral canals revealed preoperatively reduced loss of excitability on the side operated in two patients (JU and KO). Directional preponderance in these patients was toward their normal side, although this by no means follows an inviolate rule (19).

The preoperative tests of otolith function measured amounts of ocular roll to tilt that were within "normal" limits in two patients (JU, NU), and bilaterally reduced in the other two (LE and KO). Since a unilateral loss of otolith function is often manifested primarily as a reduction in counterrolling response to tilt toward the normal ear, the bilateral reduction in the magnitude of this response in patients LE and KO suggests that 1) this compensatory eye movement can be affected bilaterally by a unilateral lesion, or 2) that a unilateral defect exists but is masked by unknown compensatory factors that tend to balance the positive and negative ocular roll movement, or 3) that the otolith organs were actually affected bilaterally. The substantial asymmetry in the counterrolling response of JU found prior to surgery, in contrast, may have revealed an irritative type of disorder of her right ear since there was substantially greater than usual relative response when her right ear was superior and stimulated by gravity acting as an inward shearing force (4). The average otolith response of NU recorded by the standardized method was completely normal with regard to both magnitude and symmetry. An instability of NU's eye roll-response, on the other hand, was revealed when his diseased right ear was inferior, which correlated with the position which could trigger his symptoms and violent rotary nystagmus, certain components of which may have been recorded by our technique; however, JU manifested a 5.2°/sec (slow phase velocity) right-beating nystagmus only when her "normal" (right) ear was down, suggesting a different underlying mechanism.

The relatively poor postural equilibrium and high susceptibility to motion sickness demonstrated by all four patients gave additional evidence of active or uncompensated vestibular disturbance, but without reference to the side affected. The sudden and marked decrease in motion sickness susceptibility of all four patients after surgery points up the diagnostic importance of high levels of susceptibility, particularly in those without past history of sensitivity to motion.

Electronystagmographic, audiometric, and ocular counterrolling measurements also demonstrated labyrinthine alterations resulting from the surgical techniques. Unilateral reduction or loss of nystagmic response to suprathreshold caloric irrigation was registered by marked loss of labyrinthine response in the operated ear with directional preponderance toward the normal ear. Both the rise in threshold of the caloric irrigation as well as in the audiometric response not only indicated the operated side but also the extent of the surgical interference. As expected in KO with unilateral sectioning of his left VIIIth nerve, hearing on the same side was completely (> 100 dB) lost and the associated lateral canals were unresponsive to caloric irrigation. In NU with the one-sided loss of both the superior and inferior vestibular nerves, the temperature of the irrigating water had to be lowered 16.8° below the presurgery level that had elicited a threshold nystagmic response, and a substantial hearing loss was found. In JU and LE who sustained unilateral sectioning of the superior vestibular nerve, a caloric irrigation

threshold was measured after the water temperature was reduced by 6.0° and 5.5°, respectively, and the hearing of each was essentially preserved. These results agree with the observation (20) in a large number of patients with Ménière's disease that the caloric-response level correlates directly with pure-tone hearing loss.

Surgery apparently increased the intersessional variability of the average counterrolling response for NU, while decreasing it for LE. The below-normal overall magnitude of the counterrolling response for LE and KO found prior to surgery could be attributed to the disease process since it was changed little by the surgery which in the case of KO involved complete unilateral sectioning of the VIIIth nerve. Surgical interference in JU and LE caused a greater reduction in counterrolling when they were tilted with their diseased ear uppermost, and this change tended to make their eye roll response more symmetrical.

In summary, thresholds of caloric response of the lateral canals appeared relatively undisturbed by the disorder in these patients, but not by surgical interference that was effective in completely eliminating their tinnitus and disabling vertigo. Indications that the inner ear was the basis for the patients' symptoms and for the unilateral nature of the disorder consisted of unusual counterrolling responses, directional differences in the oculogyral illusion thresholds of response, labyrinthine response and directional imbalance to caloric (Fitzgerald-Hallpike) irrigation, as well as atypical findings in tests of pure tone discrimination, ataxia, postural disequilibrium, and motion sickness susceptibility.

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